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# RC Beams Retrofitted by Ferrocement Laminates with Addition of Alccofine

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## Abstract

This paper reports on an experimental investigation carried out to investigate the RC Beams Retrofitted by ferrocement Laminates with addition of Alccofine. Investigation into the transfer of forces across the concrete/ ferrocement interface, the effects of the level of damage sustained by the original beams prior to repair. The results show that ferrocement is a viable alternative strengthening component for the rehabilitation of reinforced concrete structures. The project has validated and evaluated the flexural behavior of RC beams with different proportions of partial replacement of cement by Alccofine in ferrocement laminates. And also concludes as Retrofitted beam corresponding to 10% and 20% of Alccofine has the highest load carrying capacity as compared to other specimen. Furthermore, after retrofitting all the specimen showed reduced crack width, large deflection at the ultimate load.

**Keywords:** RC Beams; Ferrocement Laminates; Alccofine

## Introduction

Most of the structures we lay our eyes on are invariably made of reinforced cement concrete or RCC as it is commonly called. Even though it is a wonderful construction material, but once set is very difficult to increase its strength or alter its shear or flexure strength. Another major drawback with RCC is that at most places it is largely manufactured by unskilled labour and if seemingly minor but important points, if not keep in mind leads to RCC of reduced strength. Some of these points are increase in water cement ratio, improper curing etc. Strengthening the reinforced concrete may become necessary for a number of reasons, such as sub stand detailing of the steel reinforcement and deterioration of the concrete under severe environmental conditions. Other needs for strengthening arise because either the design codes have changed that make these structures substandard or larger loads are permitted on the components of the infrastructure where extensive retrofitting is required.

A survey of existing residential buildings reveals that many buildings are not adequately designed to resist earthquakes. In the recent revision of the Indian earthquake code (IS1893:2002), many regions of the country were placed in higher seismic zones. As a result many buildings designed prior to the revision of code may fail to perform adequately as per new code. It is therefore recommended that the existing buildings be retrofitted to improve their performance in the event of an earthquake and to avoid large scale damage to life and property.

The project aims to validate and evaluate the flexural behavior of RC beams with different proportions of partial replacement of cement by alccofine in ferrocement laminates [1-3].

## Constituent Materials

The constituent materials of ferrocement are:

a) Reinforcing Mesh

b) Cement

c) Aggregates

d) Mixing Water.

### Reinforcing mesh

One of the essential components of ferrocement is wire mesh different type of wire mesh shown in Figures 1 and 2 are available almost everywhere. These generally consist of thin wires, either woven or welded into the mesh but main requirement is that it must be easily handled and if necessary, flexible enough to be bent around sharp corners.

The function of wire mesh and reinforcing rod is to provide the form and to support the mortar in its green state. In the hardened state, its function is to absorb the tensile stresses on the structure which the mortar on its own would not be able to withstand.

### Cement

The cement used should confirm to IS specifications. There are several types of cements are available commercially in the market of

**Figure 1:** Flexural testing of retrofitted RC beams specimen.

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which Portland cement is the most well-known & available everywhere. Cement of Portland variety produced today is satisfactory enough to serve the purpose of ferrocement construction.

### Aggregates

The most common aggregate used in ferrocement is sand. Sand should comply with IS standard C33 for fine aggregate. Aggregate is the term given to the inert material & it occupies 60 to 80 % of the volume of mortar. Aggregates to be used for the production of high quality mortar for ferrocement structure must be strong enough, impermeable & capable of producing a sufficiently workable mix with minimum water/cement ratio to achieve proper penetration of wire mesh.

### Mixing water

The quality of mixing water for mortar has a visual effect on the resulting hardened ferrocement. Impurities in water may interfere with setting of cement & will adversely effect the strength of cause staining of its surface & may also lead to its corrosion of ferrocement. Usually water that is piped from the public supplies is regarded as satisfactory.

## Methodology

### General

The project aims to validate and evaluate the flexural behaviour of RC beams with different proportions of partial replacement of cement by alccofine in ferrocement laminates. The behaviour of the section is studied by various aids. The entire work is split up into various activities [4,5].

1. Literature collection,
2. Theoretical study,
3. Experimental study.

**Literature collection:** The number of literature published by various authors related to strength and flexural behaviour of RC beams retrofitted with ferrocement laminates.

**Theoritical study:** In the theoretical study, the sectional properties of the beams and ferrocement laminates are determined and the maximum load carrying capacity has been carried out.

**Experimental study:** In the experimental study, the specimens are casted and subjected to curing for 28 days, after hardened, the beams are tested under two point loading for the initial crack and then the beams are retrofitted with ferrocement laminates and cured for 7 days and tested. The failure mechanism, load carrying capacity are studied.

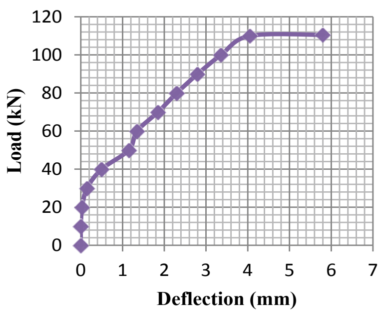


**Figure 2:** Load deflection curve for retrofitted beam with cement mortar.

## Material Properties

### Cement

Cement is defined as the material with adhesive and cohesive properties which make it capable of bonding the constituents of concrete into a compact durable mass. Cement is obtained by grinding the raw materials (calcareous materials like limestone, chalk, marine shell and argillaceous materials containing silica, alumina and iron oxide).The mixture is then burnt in a large rotary kiln at a temperature of 1300°C to 1500°C. The resulting product called clinker is cooled and ground to fine powder called cement. In this project, Ordinary Portland Cement (OPC) 43 grade is used. Tests were conducted for cement as per IS8112:1989. The physical properties of cement used in the experimental work are given in Table 1.

### Fine aggregate

Fine aggregate is added to concrete to assist workability to the concrete mix and to prevent segregation of the cement paste and coarse aggregates during its transportation. The aggregate fraction from size 150 micron to 4.75 mm is termed as fine aggregate. The fine aggregate is represented by its zone. In this project, Natural River sand conforming to IS 383:1970 is used as fine aggregate. The physical properties of fine aggregate used in the experimental work are given in Table 2.

### Coarse aggregate

The coarse aggregate is used primarily for the purpose of providing bulkiness to concrete. The aggregate fraction from size 4.75 mm to 80 mm is termed as coarse aggregate. The coarse aggregate is described by its nominal size. In this project, crushed granular aggregate of 20 mm size conforming to IS 383:1970 is used as coarse aggregate. The physical properties of coarse aggregate used in the experimental work are given in Table 3.

### Water

The quality of water is important, because impurities in it may interfere with the setting of the cement and it may adversely affect the strength of the concrete or cause staining of its surface and may

| S. No. | Characteristics | Value obtained |
|---|---|---|
| 1 | Standard Consistency | 35 |
| 2 | Initial Setting Time | 36 minutes |
| 3 | Final Setting Time | 400 minutes |
| 4 | Specific Gravity | 3.15 |

**Table 1:** Physical properties of Cement.

| S. No. | Physical property | Value obtained |
|---|---|---|
| 1 | Fineness modulus | 2.75 |
| 2 | Grading zone | I |
| 3 | Specific Gravity | 2.74 |
| 4 | Moisture Content | 0.5% |
| 5 | Water Absorption | 1.5% |

**Table 2:** Physical properties of Fine aggregate.

| S. No. | Physical property | Value obtained |
|---|---|---|
| 1 | Fineness modulus | 7.07 |
| 2 | Nominal size | 20 mm |
| 3 | Specific Gravity | 2.65 |
| 4 | Moisture Content | Nil |
| 5 | Water Absorption | 0.5% |

**Table 3:** Physical properties of Coarse aggregate.

also lead to corrosion of the reinforcement. Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic material they may be deleterious to concrete or steel permissible limits [6,7].

### Alccofine

ALCCOFINE is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. ALCCOFINE 1203 have used conforming to ASTM C989-99. Physical & Chemical Properties of Alccofine is given in Tables 4 and 5.

### Reinforcement bars and wire mesh

HYSD steel of grade Fe-500 of 8 mm and 6 mm diameters were used as Longitudinal steel and stirrups respectively. Both 8 mm bars are used as tension and compression steel. 6 mm diameter bars are used as shear stirrups. The properties of these steel bars are shown in Table 6 MS welded steel wire mesh of 2.4 mm diameter with square grids was used in ferrocement jacket. The grid is in diamond pattern. The salient properties of mesh wire used are given.

### Beam specifications

Dimension: 1000 mm × 100 mm × 150 mm

Grade of concrete: M25

Grade of Steel: Fe500

Reinforcements: 2# of 8 mm φ bars @ top

: 2# of 8 mm φ bars @ bottom

Stirrups: Two legged 6 mm φ bars @150 mm c/c.

### Ferrocement laminates specifications

Dimension: 1000 mm × 150 mm × 175 mm

Bottom Flange: 150 mm × 25 mm thick

Web [both side]: 150 mm × 25 mm thick

Mortar mix: 1:3.

### Load and supporting conditions

Load applied on the beam is two line loads. Both ends are pinned support - Arresting the all horizontal translation in pinned support. Flexure strength is one measure of the tensile strength of concrete. It is a measure of a reinforced concrete beam to resist failure in bending. It is measured by 100 × 100 mm concrete beams with span length at least three times the depth.

| Fineness (cm$^2$/gm) | Specific Gravity | Bulk Density (kg/m$^3$) |
|---|---|---|
| >12000 | 2.9 | 700-900 |

**Table 4:** Physical Properties.

| $C_aO$ | $SO_3$ | $SiO_2$ | $AL_2O_3$ | $Fe_2O_3$ | $M_gO$ |
|---|---|---|---|---|---|
| 61-64% | 2-2.4% | 21-23% | 5-5.6% | 3.8-4.4% | 0.8-1.4% |

**Table 5:** Chemical Properties.

| Water (litres/m$^3$) | Cement (kg/m$^3$) | Fine Aggregate (kg/m$^3$) | Coarse Aggregate (kg/m$^3$) |
|---|---|---|---|
| 197 | 438 | 711 | 1072 |
| 0.45 | 1 | 1.62 | 2.45 |

**Table 6:** Mix Proportions for M25 grade concrete.

## Objective of the Project

The Objective of the project is

(i) To design the reinforced concrete beams theoretically.

(ii) To calculate the load carrying capacity of the beam experimentally.

(iii) The sectional properties of the beams and ferrocement laminates are determined and the maximum load carrying capacity has been carried out.

(iv) To compare the results theoretically with the obtained experimental results.

## Mix Design for Concreting

Mix proportions for M25 grade concrete is given in Table 6.

1. Grade designation: M 25.
2. Type of cement: OPC 43 Grade.
3. Maximum nominal size of aggregate:20 mm.
4. Minimum cement content: 300 kg/m$^3$.
5. Maximum water cement ratio: 0.50.
6. Workability (Slump): 100 mm.
7. Exposure condition: Moderate.
8. Degree of supervision: Good.

## Testing of Concrete Specimens

### Casting and testing concrete beam specimens

The casting of beams is done in a single stage. The beams are casted in a mould of size 1000 mm × 100 mm × 150 mm. All the twelve beams are tested under simply supported end conditions. All the twelve beams are tested under simply supported end conditions. Out of these twelve beams, 3 beams are retrofitted beams with cement mortar and other 9 beams are retrofitted beams with cement mortar with addition of Alccofine of various proportions (10%, 20%, 30%)Two point loading is adopted for testing and spacing between two concentrated loads (Tables 7-11).

## Load Deflection Curve

In this section load deflection curves of various beams were compared. From this study the retrofitted beams are much stiffer and have great load carrying capacity than that of conventional retrofitted beams. The graph shows the ultimate load carrying capacity of the

| S.No | Diameter of bars/mesh wire | Yield strength (MPa) | Ultimate strength (MPa) | Percentage of Elongation |
|---|---|---|---|---|
| 1. | 8 mm | 520.8 | 565 | 20.3 |
| 2. | 6 mm | 500 | 545 | 25.8 |
| 3. | 2.4 mm | 400 | 511.36 | 2.52 |

**Table 7:** Testing of Steel.

| Specimen No | Compressive strength (7 days) MPa | Compressive strength (28 days) MPa |
|---|---|---|
| Sp 1 | 19.4 | 31.9 |
| Sp 2 | 21.6 | 31.2 |
| Sp 3 | 22.5 | 33.1 |

**Table 8:** Compressive strength test.

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beams. While adding 10%, 20% of Alccofine to the laminates there is increase in load carrying capacity of the beams when compared to conventional retrofitted beams and also 30% of addition of Alccofine in retrofitted beams. The results are shown on graph (Figures 2-6).

## Failure Pattern

Representative crack patterns at the conclusion of the test for the beam and specimens in the various test series are given. The cracking patterns for the specimens were quite similar and typical of flexural members when subjected to externally applied load [8-10].

## Conclusion

Based upon the results of experimental study carried out the following conclusions can be drawn:

| Specimen No | Compressive strength (7 days) MPa |
|---|---|
| A0 | 35 |
| A1 | 35.6 |
| A2 | 37.2 |
| A3 | 33 |

**Table 9:** Compressive strength of cement mortar cubes.

| Specimen 1 | | Specimen 2 | | Specimen 3 | | Specimen 4 | |
|---|---|---|---|---|---|---|---|
| Load (kN) | Deflection mm | Load (kN) | Deflection mm | Load (kN) | Deflection mm | Load (kN) | Deflection mm |
| 5 | 0 | 5 | 0.05 | 5 | 0 | 5 | 0 |
| 10 | 0 | 10 | 0.13 | 10 | 0 | 10 | 0 |
| 15 | 0 | 15 | 0.26 | 15 | 0.06 | 15 | 0.05 |
| 20 | 0.12 | 20 | 0.50 | 20 | 0.20 | 20 | 0.15 |
| 25 | 0.32 | 25 | 0.75 | 25 | 0.45 | 25 | 0.28 |
| 30 | 0.57 | 30 | 0.95 | 30 | 0.75 | 30 | 0.50 |
| 35 | 0.82 | 35 | 1.19 | 35 | 0.99 | 35 | 0.75 |
| 40 | 1.09 | 40 | 1.41 | 40 | 1.25 | 40 | 0.98 |
| 45 | 1.37 | 45 | 1.65 | 45 | 1.57 | 45 | 1.20 |
| 50 | 1.58 | 50 | 1.90 | 50 | 1.98 | 50 | 1.55 |
| 55 | 1.80 | 55 | 2.15 | 55 | 2.20 | 55 | 1.83 |
| 60 | 2.05 | 59.4 | 2.25 | 60.5 | 2.35 | 58.4 | 2.14 |
| 63.6 | 2.26 | - | - | - | - | - | - |

**Table 10:** Results of RC beams.

| Specimen NO | Initial Cracking Load (kN) | Ultimate Cracking Load (kN) |
|---|---|---|
| Specimen 1 | 90 | 110.5 |
| Specimen 2 | 95.6 | 115.7 |
| Specimen 3 | 100.5 | 119.5 |
| Specimen 4 | 93 | 106.2 |

**Table 11:** Results of retrofitted beams.

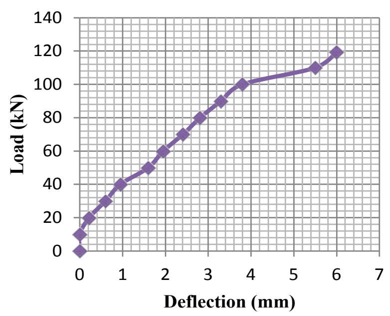


**Figure 3:** Load deflection curve for retrofitted beam with 10% addition of Alccofine.

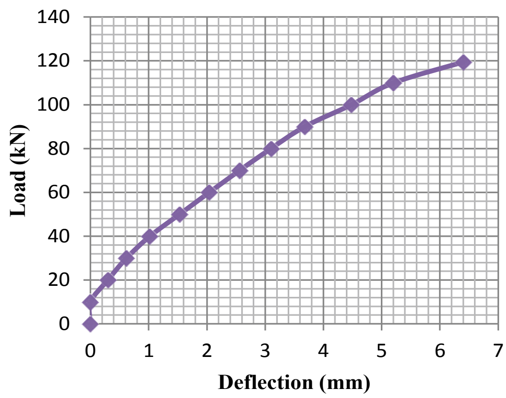


**Figure 4:** Load deflection curve for retrofitted beam with 20% addition of Alccofine.

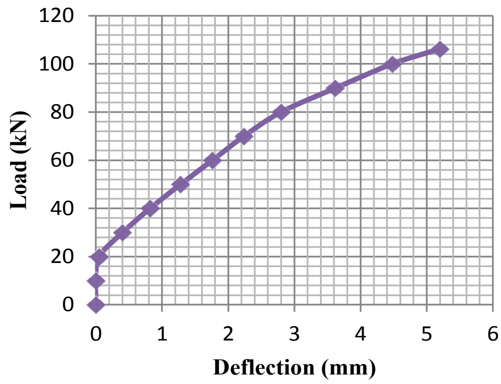


**Figure 5:** Load deflection curve for retrofitted beam with 30% addition of Alccofine.

**Figure 6:** Crack pattern of retrofitted concrete beams.

1. The beams retrofitted with wire mesh for different stress levels do not debond when loaded to failure.
2. The failure is characterized by development of shear and flexural cracks over the tension zone. The spacing of cracks is reduced for beams retrofitted with wiremesh at 45 degree for different proportions of Alccofines indicating better distribution of stress.

3. Retrofitted beam corresponding to 10% and 20% has the highest load carrying capacity as compared to other specimen.
4. After retrofitting all the specimen showed reduced crack width, large deflection at the ultimate load.

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